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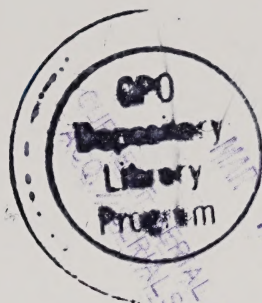
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Northeastern Area
State & Private
Forestry

Appalachian Integrated
Pest Management

Morgantown, WV

NA-TP-06-94



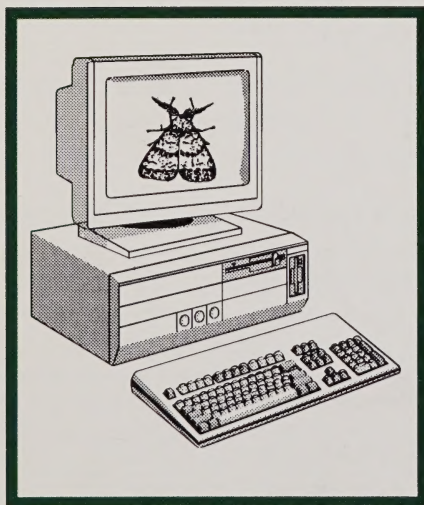
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AIPM

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Geographic Information System

Development of a Geographic Information System for Gypsy Moth Management



A
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Appalachian
Integrated
Pest
Management

Received By: JUB
6 Indexing Branch

Editor: Brenda L. Wilkins

Design & Production: Tinathan A. Coger

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Development of a Geographic Information System for Gypsy Moth Management

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May 1994



Northeastern Area
State & Private
Forestry



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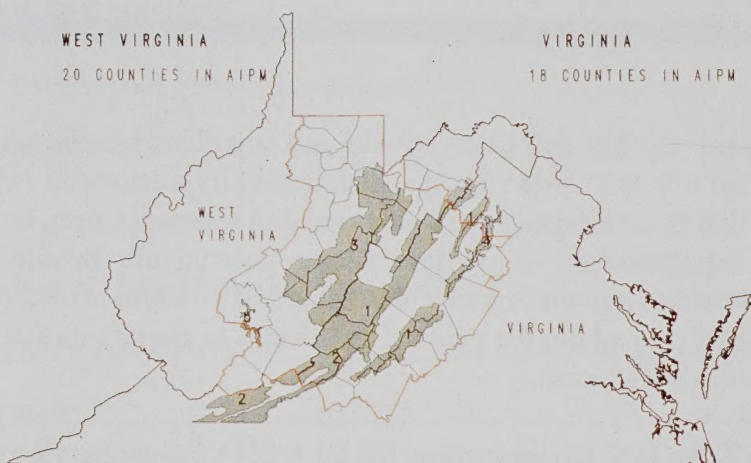
INTRODUCTION

The gypsy moth, a defoliator of oaks and other hardwoods, was imported into the United States and accidentally released in 1869. Since that time, it has spread southward and westward from its initial infestation site of Medford, Massachusetts, into the mid-Atlantic states and the Appalachian Mountains. Various methods were used throughout the years in an attempt to stop its spread, but without much success.

In 1987, the U.S. Congress directed the USDA Forest Service to initiate the Appalachian Integrated Pest Management (AIPM) Gypsy Moth Demonstration Project as a five-year (1988-1992) coordinated effort to demonstrate the effectiveness of new and existing technology for slowing the spread and managing the gypsy moth on federal, state, and private lands within the project area. The project area included all or portions of 20 counties in West Virginia and 18 counties in Virginia (Figure 1) — approximately 13 million acres.

One of the program's primary objectives was to develop and evaluate a prototype integrated pest management (IPM) structure. A computer-based geographic information system (GIS) was identified as one of the tools that would be used in implementing the IPM approach. The use of a GIS helped to satisfy the IPM objective by providing a system to collect, store, and analyze the geographically referenced data collected during the AIPM Project.

APPALACHIAN INTEGRATED PEST MANAGEMENT GYPSY MOTH PROJECT AREA



Project area size - 12.8 million acres
Area includes state lands, private lands,
and federal lands

Federal lands include:

- 1 - George Washington National Forest
- 2 - Jefferson National Forest
- 3 - Monongahela National Forest
- 4 - Shenandoah National Park
- 5 - New River Gorge National River

JANUARY 1991


Figure 1. AIPM Project Area Location, showing the federal lands included in the two-state project.

A team of GIS specialists, located at four sites, developed map products and other spatially referenced information. These items were used by AIPM's field personnel, program coordinators, and managers for:

- planning and implementing site-specific gypsy moth intervention tactics,
- project-wide decision-making, and
- dissemination of information to the public and other interested parties.

The AIPM Project was the first large-area gypsy moth IPM program to use a geographic information system.

WHAT IS A GIS?



A geographic information system can be defined as an organized collection of computer hardware and software, data, people, organizations, and institutional arrangements that allows for collecting, sorting, analyzing, and disseminating information about geographically defined areas. GIS's include a database management system (DBMS) and programs for input, manipulation, analysis, and hardcopy output of geographically referenced data. The GIS software maintains the link between the locational data and its associated database attributes.

Each data theme (for example, male moth trap catches for year X) can be stored as a separate layer in a GIS. In many situations, decisions must be made by comparing two or more different data themes. Because each of the data layers in a GIS contains locational information (they are geo-referenced), multiple layers can be overlaid within the computer, and comparisons among layers can be performed. More complex analyses can be done as well.

The results, in the form of a map or other graphic, can be viewed on the computer screen or plotted out and viewed in a hardcopy format. A GIS can be thought of as a tool that literally lets us "see" into our data and to discern otherwise obscure relationships among differing data themes.

Geographic information systems can be run on many types of computers, from microcomputers to supercomputers. The microcomputer can be used in projects of limited geographic area for such things as digitizing data from maps, data entry and manipulation, some analysis, and hardcopy output. Computers with larger capacities and more analytical power are required for areas of large geographic extent and to perform advanced applications.

Each GIS data layer (coverage) can range in size from several megabytes of computer disk space to more than one gigabyte. For this reason, "off-line" data storage in the form of high-density tapes or disks is often used.

The GIS software used by the AIPM program was ARC/INFO® and the microcomputer version, pcARC/INFO®. The Stanford Public Information Retrieval System (SPIRES®) database management system was used to maintain the tabular male gypsy moth and egg mass data prior to incorporation into the GIS.

An important aspect of using GIS technology in an IPM program is that it fosters an understanding of the interactions of pest management decision-making within the broader area of natural resource management. Through map overlays, the GIS can provide managers with the opportunity to consider seemingly disparate concerns such as gypsy moth density, ground water pollution probability, and human and political priorities. As pest managers adopt GIS technology, it is possible to improve decision-making by incorporating natural resource, economic, and political concerns. And, by developing digital map layers of pest densities, persons charged with other natural resource management responsibilities will have the opportunity to consider forest pests in the decisions they make.

AIPM GIS ORGANIZATION

The AIPM GIS operations were distributed among four sites: USDA Forest Service, Northeastern Area, State and Private Forestry, Forest Health Protection, AIPM office in Morgantown, WV; USDA Forest Service, Region 8, Forest Health office in Atlanta, GA; West Virginia University, Geology and Geography Department, Laboratory for Geographic Information Systems and Spatial Analysis in Morgantown, WV; and Virginia Polytechnic Institute and State University (VPI&SU), Entomology Department, Blacksburg, VA.

Personnel at each site were responsible for different aspects of the GIS operations and for incorporating different data layers into the overall GIS. The data layers were shared as needed among the four sites. Activities were coordinated to reduce duplication of effort and to take advantage of the unique computing facilities and technical expertise at each location.

USDA Forest Service, Morgantown, WV

The AIPM GIS Coordinator used pcARC/INFO installed on two IBM PS/2 Model 80 microcomputers. A Calcomp 9100 digitizing board was used for the input of treatment block outlines and areas of defoliation in West Virginia. A Calcomp 8-pen plotter was used in the production of maps and graphics.

The AIPM GIS Coordinator was responsible for overall coordination of GIS activities, support of the West Virginia Department of Agriculture (WVDA) gypsy moth operations (including input of gypsy moth treatment and defoliation data and the production of maps for the state), and production of special maps and graphics for use by program managers.

USDA Forest Service, Atlanta, GA

Forest Health personnel in Atlanta used the host version of ARC/INFO installed on a Data General mainframe computer. Two digitizing boards, two 80486 personal computers, two Tektronix graphic terminals, and a large format color electrostatic plotter (capable of producing plots of up to 36" by 104") were available for use. The major responsibilities in Atlanta included input and processing of gypsy moth treatment and defoliation data for Virginia, development of several base data layers within the GIS, and production of a variety of maps at different scales. The color electrostatic plotter made production of large quantities of maps possible, so many of the standard AIPM maps were produced there.

Virginia Polytechnic Institute and State University (VPI&SU)

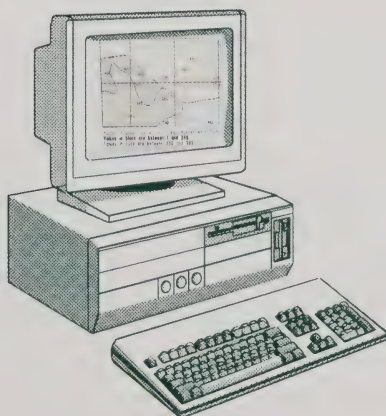
Personnel at VPI&SU had responsibility for maintaining the AIPM male gypsy moth and egg mass databases (and provided the interface between those databases, other GIS cooperators, and county, state, and federal agencies), entering male moth and egg mass data into the SPIRES DBMS, detecting and correcting errors, distributing reports, disseminating data to other state and federal agencies, and developing survey protocols and field manuals for data collection. Data from the SPIRES DBMS were formatted and transferred to a MicroVax 2000 minicomputer where ARC/INFO was installed.

VPI&SU assumed a large part of the responsibility for developing methods of representing gypsy moth sample data in maps. Examples of products supplied by VPI&SU include: (a) small format (8-1/2" by 11") maps depicting placement, monitoring, and removal of pheromone traps; (b) 1:24,000 scale maps of male moth and egg mass data; (c) county-area maps of male moth and egg mass survey data; and (d) maps depicting data over the entire project.

West Virginia University, Morgantown, WV

WVU's geoprocessing laboratory consists of fully configured GIS and image-processing capabilities on minicomputers, individual workstations, and personal computers. West Virginia University personnel consulted on AIPM GIS design and development; implemented a coordinated Morgantown Forest Service/Department of Geology and Geography GIS; developed and recommended data analysis steps; and supervised student assistants in data entry, analysis, and information products. Part-time graduate student assistants were responsible for the daily operations of data entry, database update, and output of digital and cartographic products.

Those responsible for the daily operations of the AIPM GIS functioned as a loose-knit team, and coordination was facilitated by the GIS Coordinator. The team met at least once each year with other meetings scheduled as needed. Meetings were also held between the AIPM GIS team and the cadre of field personnel involved in the AIPM effort. Several members of the GIS team attended meetings of the AIPM Planning and Steering Committees. These interactions were critical to the success of the AIPM Project. Ideas for new products were generated; prototype products were introduced; and feedback on current products, projects, and operations was solicited.





DATA COLLECTION

Data are the driving force behind any pest management program. Four data themes specific to gypsy moth were collected for AIPM each year:

- Pheromone trap catch of male moths,
- Counts of egg masses,
- Polygons delineating areas of treatment, and
- Polygons representing areas of gypsy moth defoliation.

Other pertinent data, such as jurisdictional boundaries (AIPM, state, county, and national forests), selected roads, and hydrographic features were collected and incorporated into the AIPM GIS. The gypsy moth specific data were recorded using the 1:24,000 United States Geological Survey (USGS) topographic maps as the base. Universal Transverse Mercator (UTM) grid coordinates, zone 17, were used to record geographic locations.

Sources of additional geographic data within the AIPM area were identified. These sources included U.S. Geological Survey digital line graph (DLG) data of roads and streams at 1:2,000,000 and 1:100,000 scales. DLG data at 1:100,000 scale were used in selected map products and incorporated into the AIPM GIS for a portion of the project area. Another USGS product, the Geographic Information Retrieval and Analysis System (GIRAS) for land use and land cover data (at 1:250,000 scale), was acquired and evaluated, but it was found to be too inaccurate and out-of-date for widespread use in AIPM.

In the case of both gypsy moth treatment information and defoliation, polygons were hand-sketched onto 1:24,000 USGS topographic maps, then manually digitized into the system. Male moth trapping and egg mass sampling data were both recorded on machine-readable “op-scan” forms and entered into the system electronically after verification.

VPI&SU and the Forest Health staff in Atlanta worked closely during the periods when field personnel were nearly finished with surveys for male moths and egg masses. At these times, it was necessary to produce large numbers of maps needed by managers to assist in planning subsequent phases of the AIPM project.

Because VPI&SU had the most rapid access to the male moth and egg mass data and the Forest Health office in Atlanta had production plotting capabilities, these two sites coordinated map production and distribution. They shared the responsibility for writing the computer programs (macros) that generated these types of maps.

Map production at all sites except Atlanta was limited by a lack of access to plotting devices suitable for production of large numbers of hardcopy maps. Maps produced on the available pen plotters were of good quality, but it was not feasible to generate many copies. Applications requiring production of tens or hundreds of maps were managed by sending digital files on tape to the Atlanta site where they were plotted on the electrostatic plotter. Following are specific examples:

1. Production mapping of quadrangle-level male moth trend and isoline, and egg mass survey maps. Production of male moth maps for over 200 quadrangles and egg mass maps for some of the quadrangles was initiated in 1989.

Maps were produced and plotted at Atlanta in 1989. Beginning in 1990, the quadrangle maps were produced at VPI&SU and plotted in Atlanta.

2. Production and plotting of male moth trap catch lattice-polygon maps and egg mass survey latticepolygon maps. Point data was interpolated to produce latticepolygons at VPI&SU, and the resulting data were sent to Atlanta where the maps were made. Male moth trap catch maps were made from 1988 to 1992 for the overall AIPM Project Area and for each county in the AIPM Project Area. Egg mass survey maps were made for the same areas from 1988 to 1991. Some maps were also made for sub-regional areas such as national forests, the Blue Ridge Parkway, etc.

Essentially, all operations which were performed multiple times during the field season were automated. This included operations involving the SPIRES database and the host computers at the different GIS sites. Once data were incorporated into the GIS, computer programs written in ARC/INFO's macro language (AML) were used to automate operations within the GIS environment. These included weekly creation of point coverages and many types of maps.

PRODUCTS

At the inception of AIPM, the use of a GIS in a pest management program was a relatively new concept. Many of the program participants were unfamiliar with the potential of a GIS to provide needed information. During the first year of the AIPM program, several GIS pilot projects were begun which helped to identify the needs of the program's cooperators for GIS-related products. Prototype map products were developed, and state cooperators provided suggestions for enhancements and additional products.

Some of the products developed during the pilot year were:

1. Large format (24" by 36") maps showing the year's proposed treatment blocks, airports to be used as base stations during the treatment, and a 25-mile radius drawn around each airport. These maps were used by West Virginia Department of Agriculture (WVDA) cooperators in pre-treatment meetings with aircraft pilots to help determine which treatment blocks would be treated from which airport. These were also used during treatment activities to prioritize and record treatments. Prior to the development of such maps, state personnel had no good way to see an entire treatment program for the year on one contiguous map. In order to gain a similar picture, about 50 to 70 pieced-together map sheets (1:24,000 scale) would have been needed.
2. Large format maps of the year's proposed treatment blocks, on a county-by-county basis.
3. A large format map showing the historical record of treatments for gypsy moth. This map was significant, because it showed areas that had been treated in multiple years.
4. Large format maps showing the year's treatment blocks and subsequent defoliation. This product gave managers a discrete starting point for investigating why certain treatments were not successful.

Throughout the program's lifecycle, the AIPM GIS team continued to foster the use of GIS-related products by developing prototypes, sending them out to field personnel and program managers for comment, and modifying the product based on the responses. Some of the methods used in portraying the gypsy moth lifestage information, initiated during the Maryland IPM gypsy moth project, were further developed and refined for use in AIPM. (See USDA Forest Service publication, NA-TP-07-93, "The Maryland Integrated Pest Management Gypsy Moth Project 1983-1987," for more information.)

As the program progressed and prototypes were put into use, field personnel and program managers generated many suggestions for additional products.

Products ranged in size from large format (24" by 36") to small format (8-1/2" by 11"). Some maps were needed in limited quantities (1-10); others were needed in larger quantities for broad distribution. Some of the maps that were produced for use in the field corresponded to the matching USGS 1:24,000 scale quadrangle. The AIPM Project area was covered by 376 of the USGS quadrangles, and at times, hundreds of the quad-level maps were plotted with the pertinent gypsy moth data. Production of maps and other graphics ranged from weekly summary reports of male moth trapping and egg mass summary data to yearly mapping of treatment and defoliation data.

For example, during the male moth trapping season, in which approximately 175 field personnel were involved in placing and monitoring about 12,000 male moth traps, weekly reports were sent to supervisors. These reports contained listings of errors to be corrected by surveyors and data summaries organized by county, USGS quadrangle, or political jurisdiction. Included with the tabular reports were small format maps which showed locations of traps placed or monitored as the season progressed (Figure 2). Managers could readily notice those areas which had not been monitored and investigate the cause of such omissions.

Whenever possible, the GIS was used to respond to special situations which arose in the field and had a spatial component. For example, in 1990 there were a few areas in which traps were placed later in the season than desired. This precipitated concern that traps in these areas would not adequately represent moth populations because of the chance that first flight had occurred prior to placement. In response to this, the GIS team produced a simple map of trap placement sites with color-coded symbols corresponding to placement date. Field supervisors used this map as a subjective guide when interpreting moth catch at these sites. Additional samples and explanations of common AIPM map products are shown in Figures 3-7.

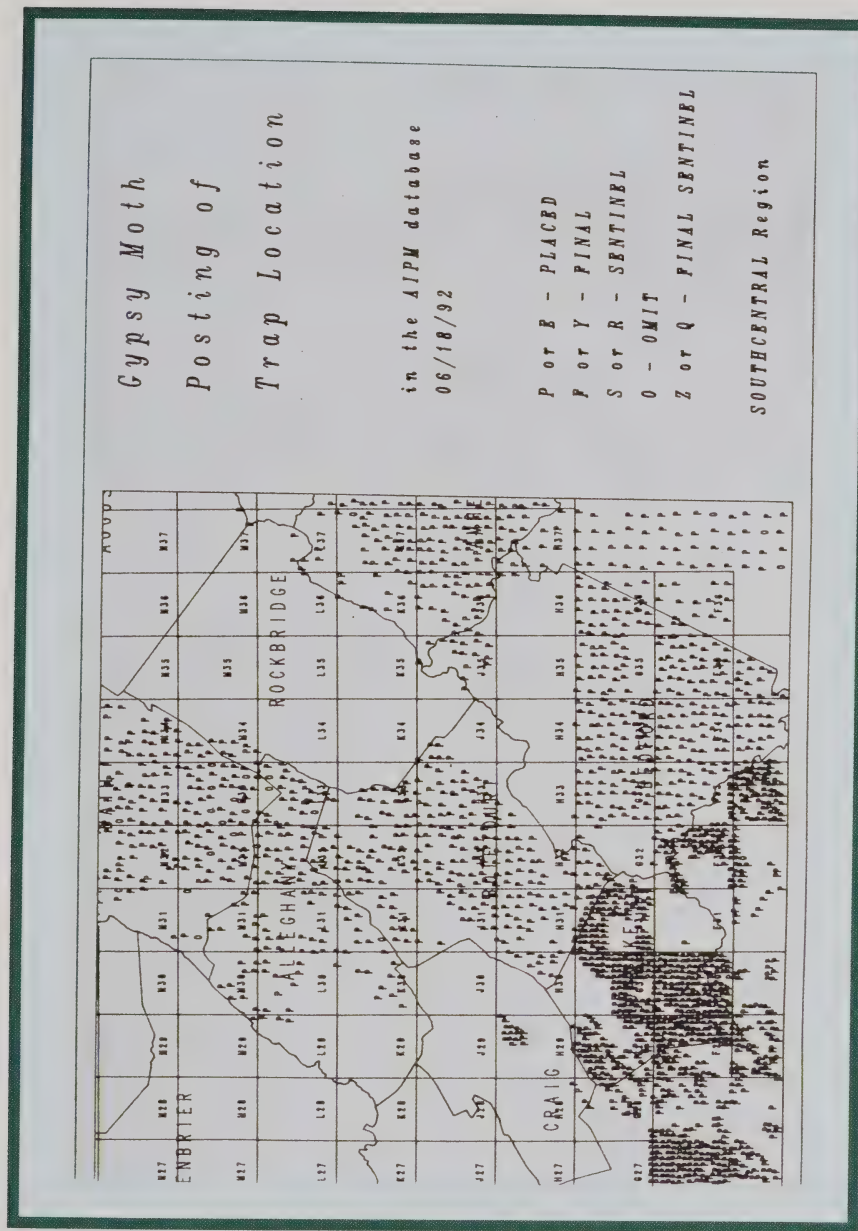


Figure 2. Gypsy moth posting of trap location map for the Northeastern portion of the AIPM project area in West Virginia and Virginia. These maps were produced weekly during the trapping season.

AIPM PROJECT AREA 1992 PHEROMONE TRAP CATCH

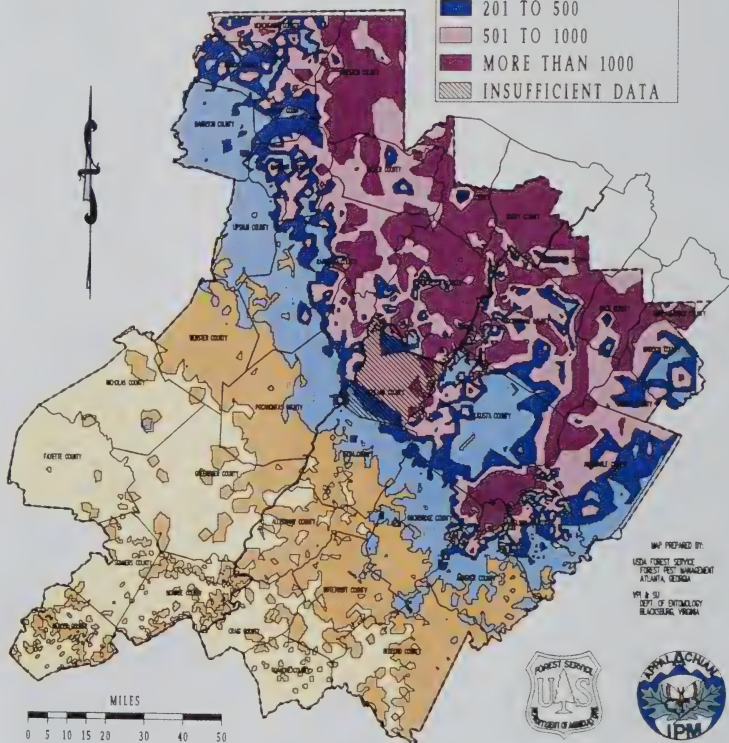
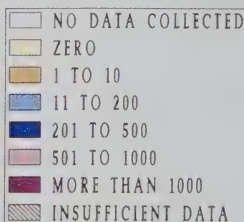
(12/14/92 DATABASE)

DATA INTERPOLATED FROM SINGLE SITE VALUES

NUMBER OF MALE GYPSY MOTHS TRAPPED



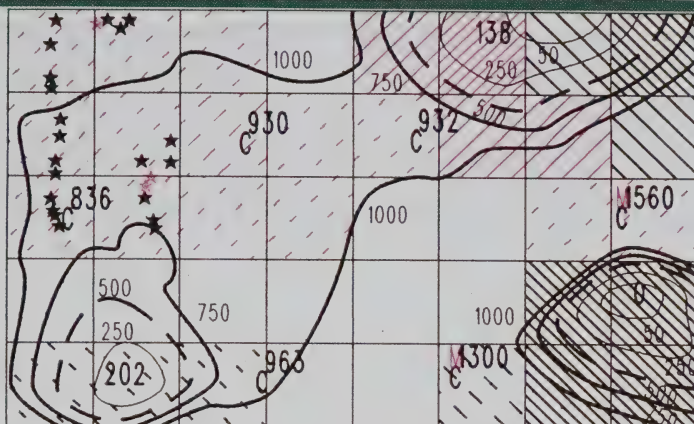
--- AIPM BOUNDARY
--- AIPM COUNTIES
--- STATE LINE



MAP PREPARED BY:
USDA FOREST SERVICE
FOREST PEST MANAGEMENT
ALABAMA REGION
RPS & SO
DEPT. OF ENTOMOLOGY
BLACKSBURG, VIRGINIA



Figure 3. 1992 pheromone trap catch map for entire AIPM Area. Trap catch values at individual sites were interpolated to create a continuous map of gypsy moth population density. This map was produced each year. Additional maps showing individual counties or other political entities were produced upon request.



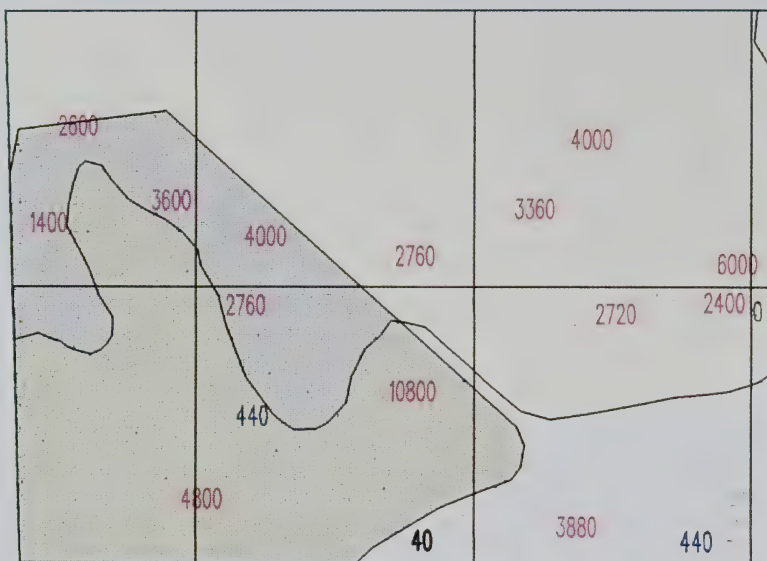
Catches > 1000 at mid-season are marked with an M.
Catches calculated from depth are marked with a C.

- 100-fold or greater decrease.
- Between 10-fold and 100-fold decrease.
- Between 5-fold and 10-fold decrease.
- Between 1.5-fold and 5-fold decrease.
- Between 1.5-fold decrease and 1.5-fold increase.
- Between 1.5-fold and 5-fold increase.
- Between 5-fold and 10-fold increase.
- Between 10-fold and 100-fold increase.
- 100-fold or greater increase.

☆ Positive egg mass site.

★ No egg masses found.

Figure 6. Male moth trend map. A portion of a 1:24,000 scale (reduced) map of gypsy moth pheromone trap data used to assist in delimiting areas for egg mass surveys. Trap catch data from individual sites are contoured. These “isomoths” represent areas of constant moth catch and are analogous to elevation contours on a topographic map. Each 1km² cell is color-coded to represent yearly change in trap catch. Catch values are posted on the maps as well as the locations of the previous year’s egg mass samples and whether they were positive or zero (red or black stars).



Values in green are where no egg masses were found.

Values in black are between 1 and 249.

Values in cyan are between 250 and 999.

Values in magenta are 1000 or greater.

- ☐ 1990 gypsy moth defoliation
- ☐ 1990 gypsy moth treatment blocks
- ☐ 1990 defoliation in treatment blocks

Figure 7. A portion of a 1:24,000 scale (reduced) map showing egg mass sample site values and the previous year's treatment and defoliation. This map was used to assist in delineating potential intervention areas.



SPECIAL PROJECTS

The applications previously discussed were components of the standard monitoring program for AIPM operations and were in place for most or all of the duration of the project. In addition to these applications, the GIS was used to assist in development of new approaches to gypsy moth management which involved monitoring and interpretation of survey results using unorthodox methodologies. One example of this was the work done in areas of low population levels.

When attention was focused on slowing the spread of gypsy moth into uninfested areas, a problem arose with use of traditional intervention activities based on egg mass survey results. Populations in areas managed to slow the spread of gypsy moth were too low to find egg masses; thus, population estimates used in decision-making were made solely on the basis of male moth captures. This translated into trapping in intensive grids, pinpointing locations of low trap catches (1 to 25), and scrutinizing the spatial relation among positive traps and those which caught no moths.

The GIS was used extensively in guiding management activities in these areas of low moth catch. Some of the most useful applications in this area involved using the GIS to play out a series of "what-if" scenarios. By constructing theoretical treatment or monitoring areas around locations of traps within certain catch categories, it was possible to estimate the resource needs for different management scenarios.

Two other major GIS applications developed during the AIPM program were the Cooper's Rock and GypMap projects:

Cooper's Rock

The Cooper's Rock project was designed to demonstrate the capability of the GIS to automate some of the decision processes used by a gypsy moth manager. ARC/INFO GIS software and the ARC macro language were used to automate the decision protocols and generate suggestions for treatment type, location, and extent. Processing was done on a Digital Equipment Corporation VAX minicomputer located at the WVU site. A prototype graphical user interface was developed as part of the project. A model format of data inputs, GIS processing, and information products was developed using the West Virginia University Research Forest and Cooper's Rock State Forest as the study area (located just east of Morgantown, WV). Eleven data layers were incorporated into the decision-making framework.

The project demonstrated the limitations of spatial analysis using a vector-based (point, line, polygon) GIS. In particular, the overlay of eleven layers of data resulted in the propagation of enormous numbers of very small polygons with little relation to features on the ground. The overlay of the eleven data layers also required extensive computer processing time.

As an alternative, processing could be done using a raster (-cell or grid-based) GIS. Raster processing avoids fragmentation of areas into virtually meaningless slivers by employing a constant grid resolution. Minimal computer processing time would be required to process the equivalent eleven-layer overlay in a raster-based GIS. A raster-based GIS was not available for use in this project.

The Cooper's Rock project was successful in illustrating the practical potential of developing a system that would be transferable after completion of the AIPM demonstration. A set of ARC macro language (AML) computer programs is available to reconstruct the maps and extract information from the demonstration.

For further information, see USDA Forest Service publication, NA-TP-09-93, "Cooper's Rock Demonstration Project: A Decision Support System for Gypsy Moth Managers," and the AIPM Demonstration Project News, October 1991.

GypMap

While the GIS proved to be crucial to many AIPM management activities, there were instances when it was obvious that improvements were needed in the structure of information flow. Because of the centralization of the GIS/DBMS, the time lag between data capture and its availability to field supervisors was too great for some applications. Indeed, some supervisors were copying egg mass data from data forms onto their own 1:24,000 scale maps before the forms were mailed to VPI&SU for entry into the data base. Although production of 1:24,000 scale maps was streamlined as much as possible, the delay caused by mailing of paper products (data forms, maps) and computer tapes was sufficient to hinder management decisions. This was particularly true for egg mass data which must be collected and processed quickly while managers are scrambling to meet time demands in proposal of treatment blocks.

It became clear that the centralized AIPM DBMS/GIS was inefficient in attending to many needs of the managers. In an attempt to provide managers with access to survey data in a decentralized system, a county-based map display and analysis system called GypMap was developed. This system contains an interface to pcARC/INFO.

GypMap was developed to provide gypsy moth managers with the tools to manipulate a variety of spatial data themes in a GIS environment. Designed to apply new technology to existing problems, it also presents an opportunity to learn from users which data layers, data features, and GIS features are most useful in gypsy moth management.

GypMap is in place in Rockbridge and Albemarle counties in Virginia and on the Glenwood Ranger District in the Jefferson National Forest, also in Virginia. Computers used for GypMap at each of these sites are either a 386 or 486 CPU microcomputer with at least a 150 megabyte hard drive, and 4 megabytes of RAM running under DOS. While the systems at each site are similar, the needs are different, so GypMap is slightly different for each area. For additional information, see the USDA Forest Service Publication, NA-TP-01-93, "Development of a Geographic Information System Technology for Gypsy Moth Management within a County: an Overview," October 1992.



RECOMMENDATIONS

Based on the knowledge and experience gained during the AIPM program, the following recommendations regarding GIS and GIS use in pest management programs are made:

- A clear statement of purpose, which includes overall objectives, specific uses, and a clear outline of responsibilities (both fiscal and for accomplishments) for using a GIS must be developed and agreed to by all cooperators involved at the beginning of a program. The GIS organization must be recognized by all cooperators as an integral part of the program, especially in the data collection, analysis, and development of geographically referenced products. Everyone should be made aware of their stake in the GIS operations.

- Establish a multi-disciplinary team to carry out the GIS operations. Appoint a GIS coordinator to implement policy and manage production of information. The GIS administrator should provide the focus for the GIS team in resolving conflicting needs and aims of various branches of the organization. The GIS team should encourage the process of looking at data in new and different ways (“Let’s see what happens if...”). The team should keep abreast of and incorporate new system architecture and improved data collection technology into the GIS.
- A comprehensive needs assessment should be completed as an essential first step in determining the organizational environment, identifying and clarifying information flows, and tailoring data collection and analysis to end-user requirements.
- A pilot project, which consists of a geographically small subset of the overall project, should be undertaken as one of the first steps in developing and refining the procedures to be used in all facets of the GIS application.
- Communication among the GIS team members and between the GIS team and the other parts of the project must be done proactively. The internal communication channels may need to be redefined so that the GIS team can provide the appropriate products to the appropriate users at the appropriate times. Recognize that existing organizational structures do not always equate to operational information needs, and that modifications of information flow structures may change over time. Establish a functional feed-back mechanism to continually review internal communication.

- Ensure that GIS products are verified in the field so that users will have confidence that the products are accurate, consistent, and complete. Ensure also that all cooperators understand the time and labor involved in creating a hardcopy product.
- A GIS for pest management must incorporate land cover (habitat) data in order for effective prediction of actions/consequences.
- Continue evaluation of options for data collection (op-scan forms vs. data recorders, sketchmapping vs. 9x9 color photography vs. 9x9 color infra-red photography vs. aerial videography for defoliation data, etc.).
- Look into new technologies, such as Global Positioning System (GPS), for assistance in collecting geographically referenced data.
- Consider methods to meet the immediate information needs of field personnel (distributed vs. centralized data).

